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The Sources of Growth of the Canadian Business Sector's CO_2 Emissions, 1990-1996

by Kaïs Dachraoui, Gerry Gravel, Tarek M. Harchaoui and Joe St. Lawrence

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Abstract

This paper examines the pattern of CO_2 emissions per unit of output (or eco-efficiency) between 1990 and 1996, decomposing the changes into an energy intensity effect, an energy mix effect and a carbon content effect. Our contribution constitutes a case study of the relative importance of these factors for a country on the downward-sloping portion of its CO_2 emission-output trajectories. Overall, our results indicate that the combination of the energy intensity and the substitution effect contributed to the decline in CO_2 emissions per unit of output. While the substitution effect was emissions reducing, it was not by itself sufficient to generate a major downward-sloping emission-output trajectory. Reductions in energy intensity typically played a substantially larger role than did the substitution effect in decreasing emissions. The carbon content effect made a positive, albeit small, contribution to the growth of CO_2 emissions per unit of output.

Keywords: Eco-efficiency, CO_2 emissions, energy intensity, economic growth

Executive Summary

A growing body of cross-country evidence suggests that 'inverted-U' relationships exist between GDP and some types of pollution. That is, while pollution may initially increase with development, there may also be a critical level of income beyond which emissions of some types of pollution decline.

The inverted-U hypothesis has generated considerable controversy, perhaps in part because so little is known regarding the factors underlying environmental development trajectories. This paper examines the factors driving the changes in Canadian CO_2 emissions over the 1990 to 1996 period.

The analytical framework rests on the decomposition of the index of CO_2 emissions per unit of output (or eco-efficiency) for the 16 largest industries producing these emissions in the business sector into: an energy intensity effect, an energy mix effect and carbon content effect.

In 1996, the Canadian business sector produced 350 million tons of CO_2 emissions, up from 326 million tons in 1990. The 16 Canadian business sector industries retained for the study accounted for 92% of CO_2 emissions on average between 1990 and 1996.

Our analysis produces four main results. First, the reduction in energy intensity significantly contributed towards the reduction in CO_2 emissions per unit of output. This finding provides some support for the hypothesis that the increase in relative energy prices played an important role in the reduction of the importance of energy per unit of output produced. Second, the energy mix or substitution effect, although contributing to the downturn of the CO_2 emissions to output ratio, played a more modest role in comparison to the energy intensity effect. Third, the contribution of the carbon content effect is negligible. Fourth, the cross-industry difference in CO_2 emissions per unit of output is due mainly to the variation in energy intensity.

I. Introduction

A growing body of cross-country evidence suggests that 'inverted-U' relationships exist between GDP and some types of pollution (see Forrest, 1995 for an overview of this literature and the policy debate it has sparked). That is, while pollution may initially increase with development, there may also be a critical level of income beyond which emissions of some types of pollution decline. Because this pattern resembles the time series of income inequality described by Kuznets, (1955), the environmental pattern has been labelled the 'environmental Kuznets curve' (EKC).

Far from being a threat to the environment in the long-term, as argued in *The Limits to Growth* and *Beyond the Limits* by Meadows *et a*l. (1972, 1992) among others, if the EKC is true, economic growth would be necessary in order for environmental quality to be maintained or improved. This is an essential part of the sustainable development argument as put forward in *Our Common Future* by the World Commission on Environment and Development (1987).

The EKC theme was also promoted by the World Bank's *World Development Report 1992* (IBRD 1992). The authors noted that: '*The view that greater economic activity inevitably hurts the environment is based on static assumptions about technology, tastes and environmental investments*' (p 38) and that '*As incomes rise, the demand for improvements in environmental quality will increase, as will the resources available for investment*' (p 39). Some have expounded this position even more forcefully: '*there is clear evidence that, although economic growth usually leads to environmental degradation in the early stages of the process, in the end the best - and probably the only - way to attain a decent environment in most countries is to become rich.*' (Beckerman, 1992).

The inverted-U hypothesis has generated considerable controversy—perhaps in part because so little is known regarding the factors underlying environmental development trajectories. This paper examines the factors driving the changes in Canadian CO_2 emissions—thereby providing a case study of the Canadian experience.[1]

While identifying the ultimate sources of the emissions trajectories is a task that is probably beyond the scope of any project, we believe that much can be learned from detailed analysis of the growth of the economic activity, the intensity of energy use, the energy mix and emissions. In this paper, we examine Canadian CO_2 emissions per unit of output (or eco-efficiency) between 1990 and 1996 and decompose the changes into an energy intensity effect, an energy mix effect and a carbon content effect. Our results provide a case study of the relative importance of these effects for a country on the downward-sloping portion of its CO_2 emission-output trajectories for the pollutant examined. Explaining the CO_2 emissions per unit of output trend is also important as it constitutes an important source of multifactor productivity gain when CO_2 emissions are treated as a bad output as shown by Harchaoui *et al.* (2002).

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[1] Our focus in this analysis will be on CO_2 emissions in part because of their importance in total emissions (78% in total).

Our analysis produces four main results: First, the reduction in energy intensity contributed more towards the reduction in CO_2 emissions per unit of output than did the substitution effect. Second, the substitution effect, although contributing to the downturn of the CO_2 emissions to output ratio, played a more modest role in comparison to the energy intensity effect. Third, the carbon content effect made a positive, albeit small, contribution to the growth of CO_2 emissions per unit of output. Fourth, there is a great deal of variation across industries in terms of CO_2 emissions per unit of output, largely due to differences in energy intensity from one industry to another.

The remainder of the paper is organized as follows: the analytical framework is presented in the next section. The data sources along with some trend analysis are presented in Section III. Section IV presents the sources of growth of the CO_2 emissions. Concluding remarks are drawn in the last section.

II. Accounting Framework

The approach applied for decomposing changes in the business sector's CO_2 emissions into distinct effects of specific factors relies on a series of simple algebraic calculations.

The CO_2 emissions of a given industry i in year t are estimated by multiplying its consumption of each fuel j by the relevant carbon content (or emission) factor (f_{ijt}). The carbon content factors quantify the average mass of CO_2 released by one joule of fuel burned. They can vary between industries and over time. Fuel consumption is measured in terms of the volume of energy (E_{ijt}).

CO_2 emissions (G_{ijt}) produced by the industry i in year t as a result of the energy consumption of type j (E_{ijt}) and the carbon content factor of fuel j (f_{ijt}) are then derived from the identity

$$G_{ijt} = f_{ijt} E_{ijt},$$

which can be rewritten as

$$G_{ijt} = f_{ijt} s_{ijt} e_{it} Q_{it}, \tag{1}$$

where

Q_{it} = The gross output of industry i in constant prices;

$s_{ijt} \equiv \left(\dfrac{E_{ijt}}{E_{it}} \right)$ = The energy consumption share of fuel type j in the total energy consumption of the industry i;

$e_{it} \equiv \left(\dfrac{E_{it}}{Q_{it}} \right)$ = The energy intensity (energy consumption per unit of output in constant prices).

CO_2 emissions based on the aggregate energy consumption of the industry i in year t are defined as

$$G_{it} \equiv \sum\nolimits_{j=1}^{J} G_{ijt} \\ = e_{it} Q_{it} \sum\nolimits_{j=1}^{J} f_{ijt} s_{ijt}. \tag{2}$$

Taking the derivative of (2) with respect to time, we get:

$$\frac{\partial G_{it}}{\partial t} = \sum_j \left(\frac{\partial f_{ijt}}{\partial t} s_{ijt} e_{it} Q_{it} + \frac{\partial s_{ijt}}{\partial t} f_{ijt} e_{it} Q_{it} + \frac{\partial e_{it}}{\partial t} f_{ijt} s_{ijt} Q_{it} + \frac{\partial Q_{it}}{\partial t} f_{ijt} s_{ijt} e_{it} \right). \tag{3}$$

Multiplying (3) by $G_{it} w_{ijt}$ where $w_{ijt} \left(\equiv \frac{G_{ijt}}{G_{it}} \right)$ is the CO_2 emission share of fuel type j within the industry i, we get

$$\frac{\partial G_{it}}{\partial t} = \sum_j \left(\frac{\left(\frac{\partial f_{ijt}}{\partial t} \right)}{f_{ijt}} + \frac{\left(\frac{\partial s_{ijt}}{\partial t} \right)}{s_{ijt}} + \frac{\left(\frac{\partial e_{it}}{\partial t} \right)}{e_{it}} + \frac{\left(\frac{\partial Q_{it}}{\partial t} \right)}{Q_{it}} \right) G_{it} w_{ijt} \\ = \sum_j \left(\frac{\partial \ln f_{ijt}}{\partial t} + \frac{\partial \ln s_{ijt}}{\partial t} + \frac{\partial \ln e_{it}}{\partial t} + \frac{\partial \ln Q_{it}}{\partial t} \right) G_{it} w_{ijt}. \tag{4}$$

Taking the integral of (4), we get for the continuous case:

$$\int_t^{t+1} \frac{\partial G_{it}}{\partial t} \equiv \Delta G_{it} \\ = \int_t^{t+1} \sum_j \frac{\partial \ln f_{ijt}}{\partial t} G_{it} w_{ijt} + \int_t^{t+1} \sum_j \frac{\partial \ln s_{ijt}}{\partial t} G_{it} w_{ijt} + \int_t^{t+1} \sum_j \frac{\partial \ln e_{it}}{\partial t} G_{it} w_{ijt} \\ + \int_t^{t+1} \sum_j \frac{\partial \ln Q_{it}}{\partial t} G_{it} w_{ijt}. \tag{5}$$

Rewriting for the discrete case yields the approximation:

$$\frac{\Delta G_{it}}{\bar{G}_{it}} \approx \sum_j \bar{w}_{ijt} \left[\ln \left(\frac{f_{ijt+1}}{f_{ijt}} \right) + \ln \left(\frac{s_{ijt+1}}{s_{ijt}} \right) + \ln \left(\frac{e_{it+1}}{e_{it}} \right) + \ln \left(\frac{Q_{it+1}}{Q_{it}} \right) \right] \tag{6}$$

where

$$\begin{aligned} \frac{\Delta G_{it}}{\bar{G}_{it}} \approx & \sum_j \bar{w}_{ijt} \ell n \left(\frac{f_{ijt+1}}{f_{ijt}} \right) && \text{Carbon content effect} \\ & + \sum_j \bar{w}_{ijt} \ell n \left(\frac{s_{ijt+1}}{s_{ijt}} \right) && \text{Substitution effect} \\ & + \ell n \left(\frac{e_{it+1}}{e_{it}} \right) && \text{Energy intensity effect} \\ & + \ell n \left(\frac{Q_{it+1}}{Q_{it}} \right) && \text{Real output growth effect,} \end{aligned} \tag{7}$$

$$\text{where } \bar{G}_{it} \equiv \frac{(G_{it+1} + G_{it})}{2} \text{ and } \bar{w}_{ijt} \equiv \frac{(w_{ijt+1} + w_{ijt})}{2}.$$

Equation (7) has the following heuristic interpretation: the growth rate of CO_2 emissions of the industry i can be decomposed into four components, which are the weighted sum of growth rates. The weights are defined in terms of CO_2 emission shares that vary over time, thereby capturing the changes in the structure of the economy.

The carbon content factor (f_{ijt}) tells how much of the reduction in emitted CO_2 is due to the reduced energy content of fuel type. If the CO_2 content did not change from one year to the next, which is often assumed, then $\sum_j \bar{w}_{ijt} \ln\left(\frac{f_{ijt+1}}{f_{ijt}}\right)$ will be zero. The term $\ln\left(\frac{e_{it+1}}{e_{it}}\right)$ is the energy effectiveness effect, that is the reduction in CO_2 emissions that arise from the use of technology that saves energy. The substitution effect $\sum_j \bar{w}_{ijt} \ln\left(\frac{s_{ijt+1}}{s_{ijt}}\right)$ measures the substitution between different forms of energy as a result of different incentives, including changes in energy relative prices. Decreasing the share of oil (substituting to other less polluting sources of energy) reduces CO_2 emissions, and hence results in a negative substitution effect. Finally, the production term $\ln\left(\frac{Q_{it+1}}{Q_{it}}\right)$ captures the extent to which economic growth affects CO_2 emissions. For example, rapid economic growth is likely to generate an increase in CO_2 emissions.

Equation (1) can also be written as

$$g_{ijt} = f_{ijt} s_{ijt} e_{it},$$

where $g_{ijt} = \frac{G_{ijt}}{Q_{it}}$, which is the CO_2 emission of the industry i attributable to the energy form j per unit of output of the same industry. Hence, the aggregate CO_2 emission per unit of output for the industry i can then be written as

$$g_{it} = \frac{G_{it}}{Q_{it}} = \sum_j \frac{G_{ijt}}{Q_{it}} = \sum_j g_{ijt}.$$

The decomposition made earlier for CO_2 emissions growth rate can then be carried for CO_2 emissions per unit of output. Therefore, the growth rate of CO_2 emissions per unit of output is decomposable into the sum of three components: the carbon content effect, the substitution effect and the energy intensity effect.[2]

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2 More specifically, $\frac{\Delta g_{it}}{g_{it}} \square \sum_j \bar{w}_{ijt} \ln\left(\frac{f_{ijt+1}}{f_{ijt}}\right) + \sum_j \bar{w}_{ijt} \ln\left(\frac{s_{ijt+1}}{s_{ijt}}\right) + \ln\left(\frac{e_{it+1}}{e_{it}}\right)$. Note also that whether the decomposition is expressed in terms of CO_2 emissions or in terms of CO2 emissions per unit of output, the weights $w_{ijt}\left(\equiv \frac{G_{ijt}}{G_{it}}\right)$ remain unchanged.

III. *The Data Sources and Descriptive Analysis*

The data used in this study are obtained from two different sources, both of which are organized around the accounting framework of Statistics Canada's Input-Output Tables: The Material and Energy Flow Accounts (MEFA) (see Statistics Canada 1997) and the Canadian Productivity Accounts. Using these data sources, we put together a dataset that comprises series on CO_2 emissions, energy consumption by type of commodity, the carbon content factor of each type of energy and real output for 47 industries of the Canadian business sector over the 1990-1996 period. The information by energy type was not readily available prior to 1990.

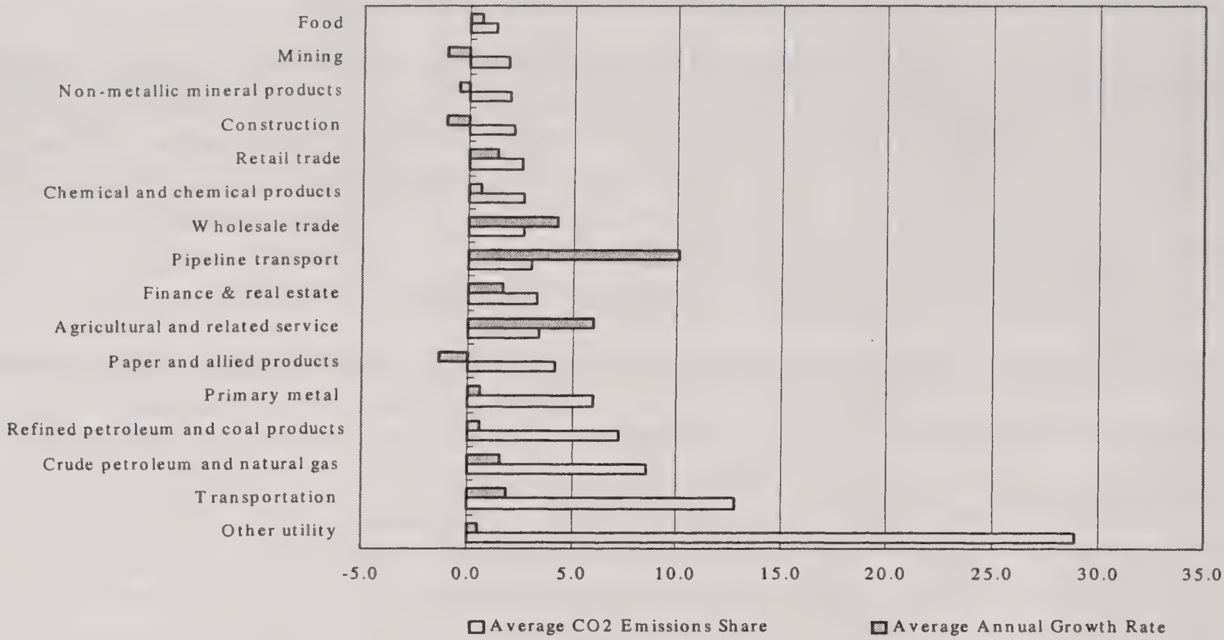
The MEFA records, in significant detail, the forms of energy consumed and the CO_2 emissions produced by various industries in Canada. These emissions data are obtained from the application of carbon content factors developed by Environment Canada to the MEFA energy consumption data. Eleven energy commodities are accounted for in the MEFA: coal, crude oil, natural gas, liquid petroleum gases, electricity, coke, motor gasoline, diesel fuel, aviation fuel, light fuel and heavy fuel oil. Emissions of CO_2 are primarily related to the combustion of fossil fuels (more than 90% of Canadian emissions result from this activity). The quantity of CO_2 produced per unit of fuel burned does not vary significantly with the conditions of combustion. In all processes where fossil fuels are burned, essentially all of the carbon found in the fuel is ultimately converted to CO_2. Emissions for each industry are calculated by fuel type, and published as an aggregate.

There are also non-combustible uses of fossil fuels that result in the release of CO_2. These are related to the use of fuels as feedstocks in certain industries, such as the refined petroleum products industry. The emission factors developed by Environment Canada for these sources are combined with MEFA data on feedstock energy commodity use to estimate the associated carbon dioxide emissions. Aside from fossil fuel-related sources, several industrial processes produce significant quantities of CO_2: Cement and lime production, ammoniac production and natural gas production. The CO_2 emissions associated with each of these non-fuel combustion sources are included in this study. However, the CO_2 emissions from the combustion of biomass (wood waste and fuel wood) are not part of our investigation. These are assumed to be offset by the natural uptake of carbon dioxide due to forest growth and, therefore, not to make a net contribution to Canadian emissions.

Industry output is measured as a Fisher chained index of real gross output. Gross output is equal to sales or receipts and other income, plus inventory change.

In 1996, the Canadian business sector produced 350 million tons of CO_2 emissions, up from 326 million tons in 1990. Out of the 47 industries of the Canadian business sector, sixteen of them, which maintained their share in terms of CO_2 emissions relatively constant over the period, generated the bulk of the 1.2% average annual growth rate of the business sector's CO_2 emissions (see Figure 1). The remainder of the empirical results will pay particular attention to these 16 industries, which accounted for 92% of CO_2 emissions on average between 1990-1996.

Figure 1. Pattern of CO_2 Emissions at the Industry Level, 1990-1996



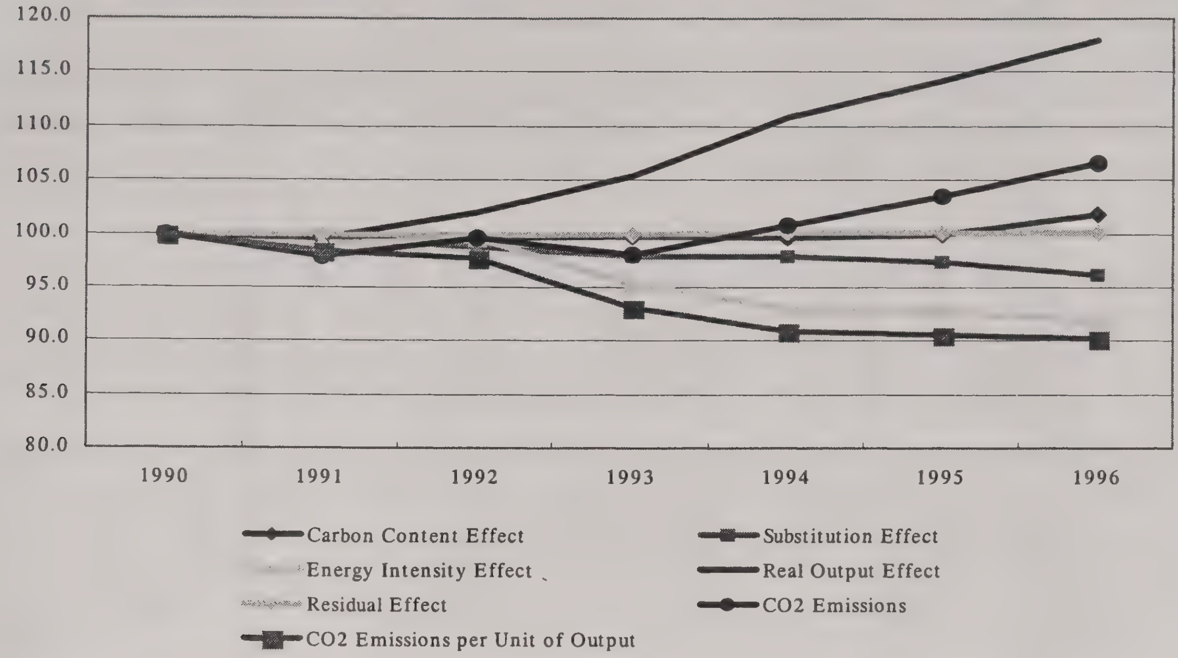
These 16 industries display a different pattern depending whether we analyse their behaviour in terms of growth or industry CO_2 emissions share. For example, although other utility industries accounted for 29% of the business sector CO_2 emissions, the growth rate of their CO_2 emissions increased at a modest 0.5% on average during the 1990-1996 period. At the other end of the spectrum, pipeline transport showed the highest growth of CO_2 emissions of the business sector (9.6%), but accounted for a modest 2.9% of total CO_2 emissions.

There are some regularities in the pattern of CO_2 emissions for the Canadian business sector: industries that account for the largest share of CO_2 emissions are those that displayed the most modest growth rate of CO_2 emissions during the 1990-1996 period. This is evidenced by the negative, albeit small, coefficient of correlation between the industry CO_2 share and their CO_2 growth rate for these 16 industries (-0.09). The negative relationship is, however, more striking for the five largest industries (-0.23).

IV. Analysis of the Results

This section quantifies the percentage points contribution of the substitution effect, the carbon content effect and the energy intensity effect to the growth of CO_2 emissions per unit of output for each of the 47 industries over the 1990-1996 period. Because our decomposition formula defined in (7) is based on a first order approximation, we expect to see a small approximation error appended to the factors that underlie the trend of CO_2 emissions or the CO_2 emissions per unit of output. The sources of growth of CO_2 emissions per unit of output obtained at the industry level are then aggregated to the level of the business sector using superlative index techniques which capture the structural changes that occurred during this time period.

Figure 2. Decomposition of CO_2 Emissions Growth for the 16 Largest Emitters, Canadian Business Sector (1990=100)



Recall that the decomposition formula defined in (7) holds for both the CO_2 emissions and the CO_2 emissions per unit of output, a type of partial eco-efficiency indicator. The results provided below examine the sources of growth for both of these variables.

Figure 2 shows the aggregate trends for CO_2 emissions and their underlying factors over the 1990-1996 period. The business sector CO_2 emissions grew at 1.2% per year on average. Had the trend in CO_2 emissions been driven exclusively by economic growth, CO_2 emissions would have posted a 2.8% average annual growth rate during this period. However, owing primarily to the decline in the energy intensity (-1.3%) combined with a substitution between different forms of fuel (-0.6%), the economic growth effect has been significantly mitigated.

There is a great deal of variation across industries in terms of the average growth of CO_2 emissions as indicated by Table 1. In agriculture and pipeline transport, the substitution effect and the energy effects jointly reinforced the economic growth effect, with the result that these industries report the fastest average growth rate of CO_2 emissions over 1990-1996. Wholesale trade is another industry where the CO_2 emissions growth rate was substantial (4.1% on average). In this instance, however, the economic growth effect drove all of the CO_2 emissions growth since the other effects cancel each other.

Table 1. Sources of CO_2 Emissions Per Unit of Output: 1990-1996

	Average industry share in total CO_2 emissions	Growth rate of CO_2 emissions (1)	Growth rate of real output (2)	Growth rate of CO_2 emissions per unit of output (1) *minus* (2)	Carbon content effect	Substitution effect	Energy intensity effect	Residual error
	Percentage				Percentage points contribution to CO_2 per unit of output growth			
Agricultural and related services	3.4	5.8	2.5	3.3	0.1	0.2	3.0	0.0
Mining	1.8	-1.0	0.0	-1.1	-0.1	0.3	-1.3	0.0
Crude petroleum and natural gas	8.5	1.6	5.5	-3.9	-0.9	-1.7	-1.3	0.0
Food	1.2	0.6	1.5	-0.9	-0.1	-1.0	0.3	-0.1
Paper and allied products	4.1	-1.4	2.4	-3.8	-0.1	-1.8	-1.9	0.0
Primary metal	5.9	0.6	3.7	-3.1	0.0	-1.4	-1.6	0.0
Non-metallic mineral products	1.9	-0.4	-0.8	0.4	-0.1	0.1	0.3	0.0
Refined petroleum and coal products	7.3	0.6	1.3	-0.7	3.7	0.3	-4.7	0.0
Chemical and chemical products	2.6	0.6	1.6	-1.1	-0.1	0.1	-1.0	0.0
Construction	2.1	-1.0	-2.2	1.2	0.4	0.2	0.7	-0.1
Transportation	12.8	1.8	2.5	-0.7	0.3	-0.2	-0.8	0.0
Pipeline transport	2.9	9.6	7.8	1.8	-0.1	0.2	1.7	0.0
Other utility	28.8	0.5	2.6	-2.1	0.1	-0.6	-1.6	0.0
Wholesale trade	2.6	4.1	4.4	-0.3	-0.2	-1.3	1.2	0.0
Retail trade	2.5	1.4	2.4	-1.1	-0.5	-0.1	-0.5	0.0
Finance and real estate	3.3	1.6	4.6	-3.0	2.8	-1.0	-4.8	0.0
Business Sector	**100.0**	**1.2**	**2.8**	**-1.7**	**0.3**	**-0.6**	**-1.3**	**0.0**

Note: Numbers may not add up due to rounding.

Transportation and crude petroleum and natural gas, two major producers of CO_2 emissions, experienced, respectively, a 1.8% and 1.6% average growth of CO_2 emissions. This moderate growth is the result of different contributions of the various underlying factors. In the case of crude petroleum and natural gas, the 5.5 percentage point contribution of the economic growth effect was significantly reduced by the combination of the other factors (-3.9 percentage points), amongst which the substitution effect contributed the most. Similarly, for transportation, the combination of the substitution effect and the energy intensity effect significantly reduced the economic growth effect.

Other utility industries recorded the slowest growth of CO_2 emissions amongst the largest producers of CO_2 emissions. This is the result of a -1.6 percentage point contribution of the energy intensity effect, followed by a -0.6 percentage point contribution of the substitution effect (corresponding to the average of the business sector).

Figures 3a to 3c, which use the data reported in Table 1, provide a cross-industry comparison of the sources of growth for CO_2 emissions per unit of output. Figure 3a shows the difference between the average annual growth rate of output and CO_2 emissions across industries over the 1990-1996 period. This difference can be considered as a partial productivity measure, an important source of multifactor productivity gain when CO_2 emissions are accounted as a bad output.

Over this period, the business sector experienced a 1.6% decrease in CO_2 emissions per unit of output. The majority of the industries reported this type of efficiency gain with the exception of pipeline transport and agriculture. These gains are particularly striking for the largest producers of CO_2, reaching -3.9% for crude petroleum and natural gas, -2.1% for other utility and a moderate -0.7% for transportation. These gains are primarily the result of two factors reinforcing each other: a drop in the energy intensity (Figure 3b) combined with the substitution towards sources of energy that are less intensive in terms of CO_2 emissions (Figure 3c).

Figure 3b plots the energy intensity of output across industries. Agriculture and pipeline transport industries, which experienced the fastest growth rate of CO_2 emissions per unit of output as indicated by Figure 3a (3.3% and 1.8% respectively), are also those that reported the highest growth of energy intensity (3% and 1.7% respectively). In contrast, the majority of other industries reported a decline in the energy intensity of their output. It appears that agriculture and pipeline transport were the only major CO_2 emitters that did not benefit from an energy saving technology.

Figure 3c, which reports the industry variation of the substitution effect, mirrors the pattern reported by the energy intensity of output (Figure 3b): the majority of industries reported major shifts from fuel types that are CO_2 intensive towards those less intensive in terms of CO_2 emissions. Agriculture and pipeline transport are the most notable exceptions. Figure 3d indicates that the carbon content factors contributed moderately to the reduction of the CO_2 per unit of output across industries compared to the energy intensity and the substitution effects.

Figure 3a. Growth of CO_2 emissions and output at the industry level, 1990-1996 (average annual growth rate in percentage)

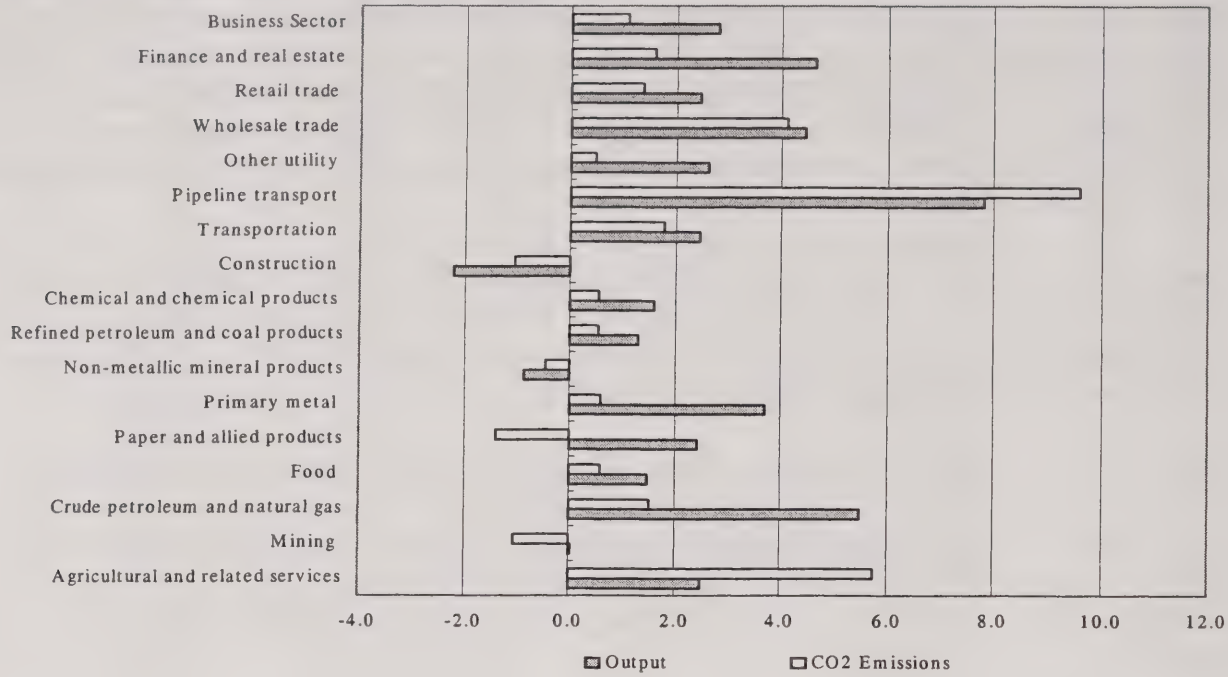


Figure 3b. Contribution of the energy intensity factor to the CO_2 emissions average annual growth rate at the industry level, 1990-1996 (percentage points)

Figure 3c. Contribution of the substitution effect to the CO_2 emissions average annual growth rate at the industry level, 1990-1996 (percentage points)

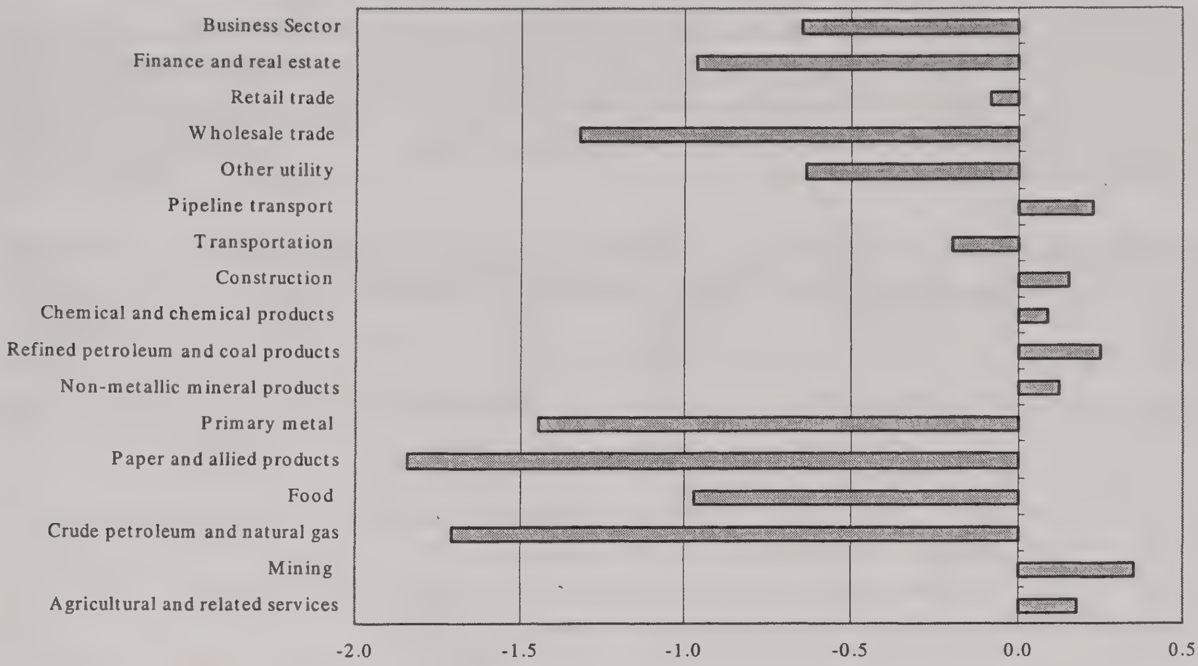
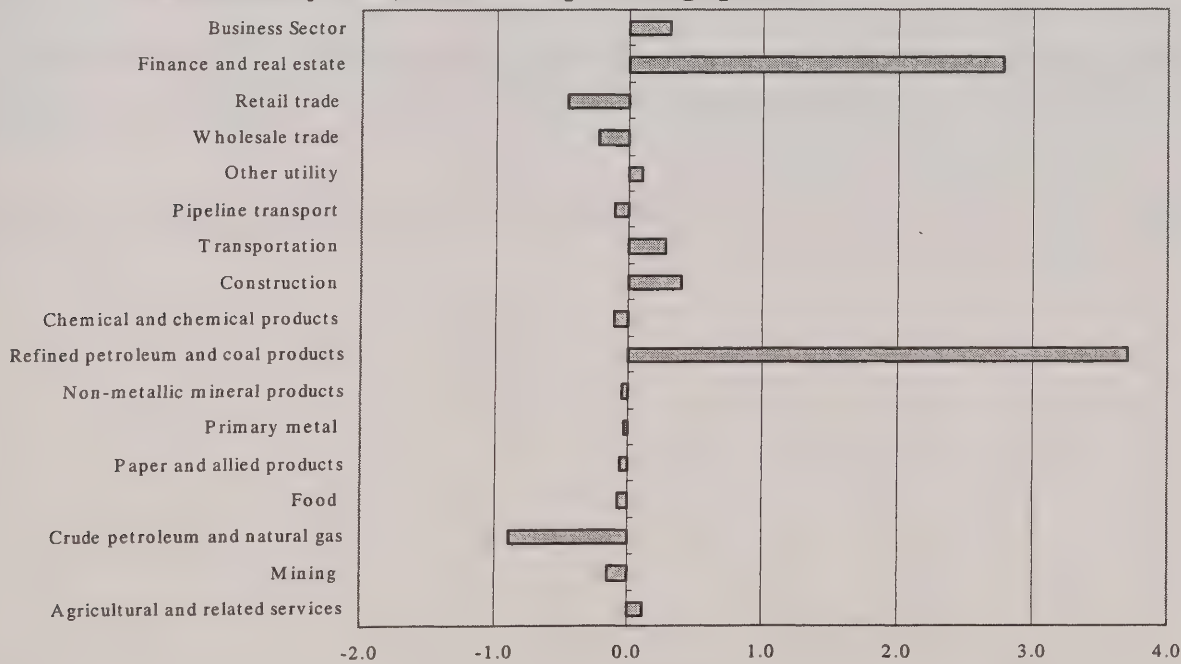


Figure 3d. Contribution of the emissions factor CO_2 emissions average annual growth rate at the industry level, 1990-1996 (percentage points)



V. Conclusion

In this paper we have decomposed the observed changes in the CO_2 emissions per unit of output and identified the effects of changes in the energy-output intensity, the substitution effect across different forms of energy and the carbon content of each form of energy. The objective is to offer insights into the trends at work in a country that appears to be on a downward-sloping portion of its CO_2 emissions-output trajectories.

The main contribution of this paper was to quantify which factors were large enough to offset the effects of overall economic growth on CO_2 emissions between 1990 and 1996. Several results emerged: First, the reduction in energy intensity significantly contributed towards the reduction in CO_2 emissions per unit of output. This finding provides some support for the hypothesis that the increase in relative energy prices played an important role in the reduction of the importance of energy per unit of output produced.[3] Second, the substitution effect, although contributing to the downturn of CO_2 emissions to output ratio, played a more modest role in comparison to the energy intensity effect. Third, with a 0.3 percentage point increase, the contribution of carbon content reinforces the economic growth effect rather than offsets it as does the energy intensity and the substitution effects. Fourth, the cross-industry difference in CO_2 emissions per unit of output is due mainly to the variation in the energy intensity.

[3] Between 1990-1996, energy relative prices increased 0.9% per year on average.

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